

Balloon Program Update

To the Astrophysics Advisory Committee

Debora Fairbrother
Balloon Program Office
Suborbital and Special Orbital Projects Directorate
Wallops Flight Facility

October 28, 2019



Strategic Objective:

Enable discovery through conduct of frequent scientific balloon flight opportunities for NASA scientific, technology development, and educational investigations.

Balloons provide low-cost, quick response, near space access for:

- Conducting cutting-edge research.
- Developing technologies to enable future spacecraft science missions.
- Advancing lighter-than-air platform technologies.
- Providing Calibration and Validation of on-orbit instrumentation.
- Enabling Hands-on Training of the next generation of scientists and engineers.

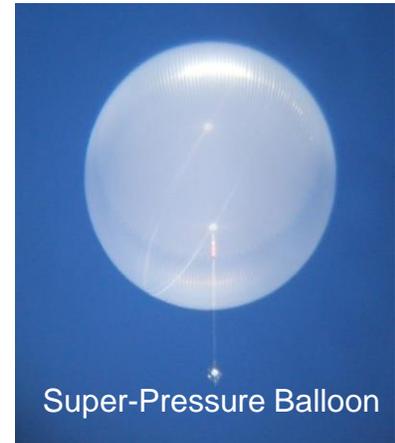
Annual Program Snapshot

8-12 Launched

3+ campaigns

300+ ugrad/grad students participate

40+ Research Institutions



Super-Pressure Balloon



Flight Manifest

Principal Investigator (PI) / Institution / Instrument	Discipline	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
Palestine, Texas	Summer 19												
Jones / Princeton / SuperBIT	IR-Submillimeter	<i>Cancelled out by PI</i>											
Kogut / GSFC / PIPER	IR-Submillimeter	<i>Cancelled out by BPO</i>											
Chakrabarti / UMass / PICTURE-C	UV / Visible	<i>Cancelled out by BPO</i>											
Kogut / GSFC / BOBCAT	IR-Submillimeter	<i>Cancelled out by BPO</i>											
Fort Sumner, New Mexico	Fall 19												
Kogut / GSFC / BOBCAT	IR-Submillimeter			◆		◇	<i>2nd Flight Cancelled out by PI</i>						
Fields / CSBF / LDB test	Test Flight				◆								
Gopalswamy / GSFC / BITSE	Solar and Heliophysics				◆								
Guzik / LSU / HASP	Student Flight Project				◆								
Fischer / GSFC / 11 MCF PiggyBack	Test Flight				◆								
Fischer / GSFC / Big 60 Qual	Test Flight	<i>Cancelled out by BPO due to not able to meet minimum duration</i>											
Chakrabarti / UMass / PICTURE-C	UV / Visible				◆								
Toon/JPL/Remote/Bailey / VATech / GLO	Upper Atmosphere				◆								
Kogut / GSFC / PIPER	IR-Submillimeter					◆							
Young / SwRI / THAI-SPICE (Hand Launch)	UV / Visible						◆						
Tang/JPL/RECKTANGLE (Hand Launch)	IR-Submillimeter						◆						
Livesey / JPL / SWITCH (Hand Launch)	IIP / Upper Atmosphere						◇						
Kerber/UMB/MATTADOR (Valve Down)	Upper Atmosphere	<i>Cancelled out by PI</i>											
McMurdo, Antarctica	Winter 19												
Salter / CSBF / TRAVALA	Test Flight							◇	◇				
Binns / WUSTL / SuperTIGER	Cosmic Ray/Particle							◇					
Devlin / UPENN / BLAST	IR-Submillimeter								◇				
Wanaka, New Zealand	Spring 20												
SPB Test Flight / Boggs / UCSD / COSI-2	Test Flight / COSI MoO											◇	
Salter / CSBF / TRAVALB	Test Flight										◇	◇	

Following the series of balloon leaks (SIFT FY18, FIREBALL FY18, Super-TIGER FY19, & X-Calibur FY19), the Balloon Program outlined and conducted a series of inflation tests.

The purpose of these tests was two fold:

Crew Chief Training:

- Required to give Crew Chief’s in-training more experience in the choreography required for a balloon launch. Replicates a balloon launch except for releasing the simulated payload from the launch vehicle.

Leak Investigation:

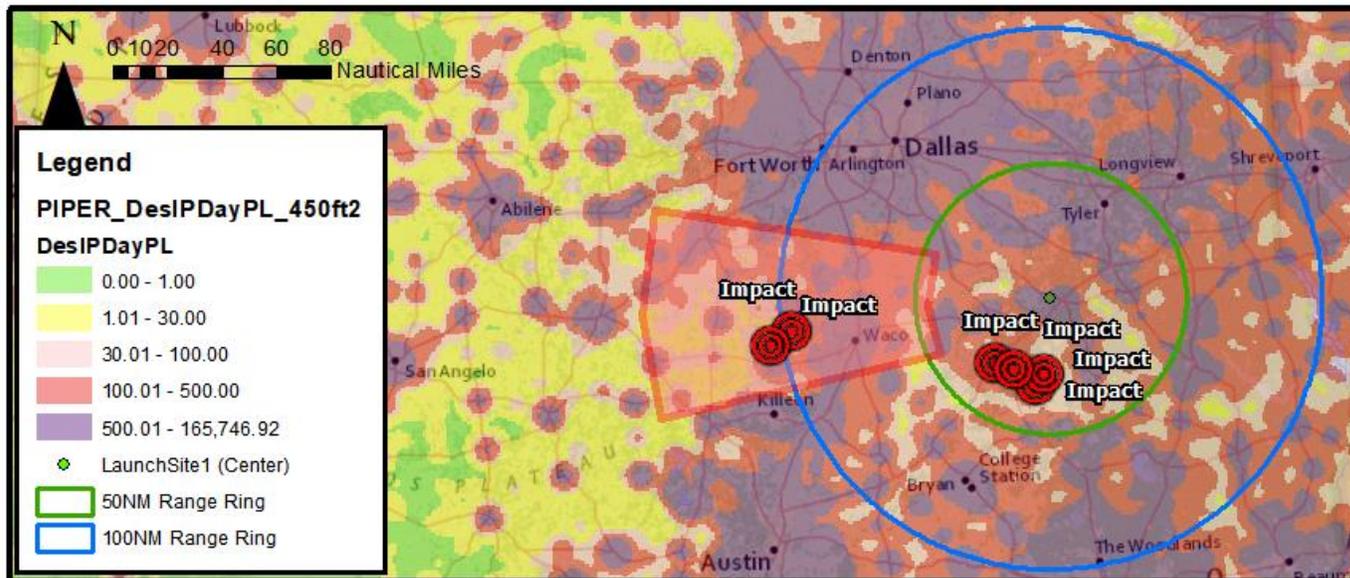
- Recent leaks tied to updated operational procedures to satisfy new safety requirement to have launch collar released prior to release from the launch vehicle. Collar launch release angle and location varied in testing.

A total of 6 moored balloon inflation tests were conducted between March and June 2019.

- No root cause for leaks determined during testing.
- The following items were learned:
 - Launch Collar can induce damage
 - Level of damage reduced with higher collar release angle
 - Collar electronics functioned 100% during all CCT (new ACER system)
 - Post test inspections of balloon carcass were extremely valuable
 - Balloon bubble angle reduced when collar location lowered

The FY19 Palestine Campaign was cancelled due to the recent balloon leaks and the higher populations around the Palestine, Texas launch location.

The three payloads (PIPER, BOBCAT, and PICTURE-C) were transferred to the FY19 Fort Sumner campaign. Super-BIT made the decision to fly out of Timmons, Canada prior to the cancellation of the Palestine campaign by the Balloon Program and concurred to by NASA HQ.



Trajectories simulations for SIFT and Super-TIGER Sized Leaks on different balloon size conducted. Red Dots on left are impact locations.

Safety requires pre-launch predicted impact must target GREEN areas to ensure NASA risk criteria is met.

The FY19 Fort Sumner Campaign was extremely successful!

Operations Schedule:

- BOBCAT successfully flown 8/22/19; declared mission and science success.
- 11MCF Piggyback (formerly Big 60 Payload) successfully flown 9/4/19; declared mission and science success.
- HASP successfully flown on 9/5/19; declared mission and science success.
- BITSE successfully flown on 9/18/19; declared mission and science success.
- LDB Test Flight successfully flown on 9/23/19; declared mission and science success.
- PICTURE-C successfully flown on 9/28/19; declared mission and science success.
- JPL-Remote successfully flown on 10/7/19; declared mission and science success.
- PIPER successfully flown on 10/14/19; declared mission success and science status TBD.
- THAI-SPICE successfully flown on 10/16/19; declared mission and science success.
- RECKTANGLE successfully flown on 10/17/19; declared mission and science success.
- SWITCH successfully ground tested on 10/19/19; declared mission and science success.

Modified Operations:

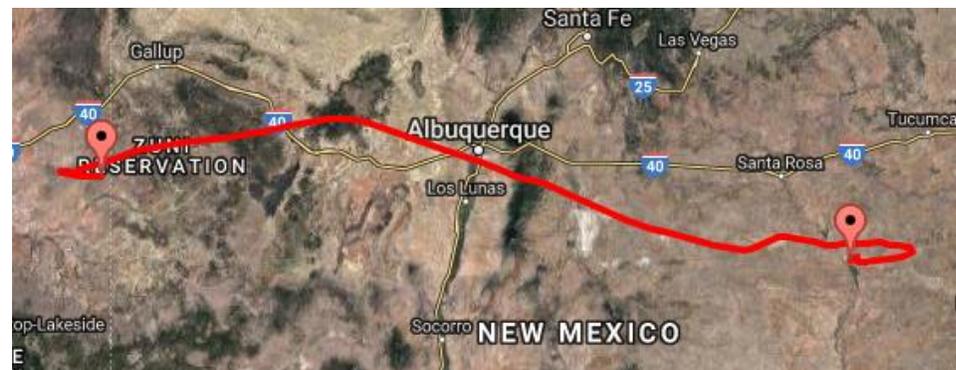
- BPO/CSBF has gone back to collar release at 85 to 90 degrees.
- BPO/CSBF has gone back to using two observers to call for collar release.
- BPO/CSBF lowered the collar placement on the balloons.
- BPO/CSBF evaluated reducing ballast and/or changing balloon sizes to reduce Launch Stress Index (LSI) for high LSI missions (changes not always made due to science).



Balloon-Borne Cryogenic Telescope Testbed (BOBCAT) – Flight 696N *Dr. Alan Kogut, NASA GSFC*

Atmospheric emission limits instrumental sensitivity at far-infrared wavelengths. BOBCAT develops technology for a balloon platform to improve far-IR sensitivity by a factor of 100,000 compared to ground-based or airborne (SOFIA) facilities. BOBCAT is a proof-of-principle demonstration for ultra-light balloon dewars. It will validate the construction techniques and in-flight operations and characterize the cryogenic performance of the dewar at float.

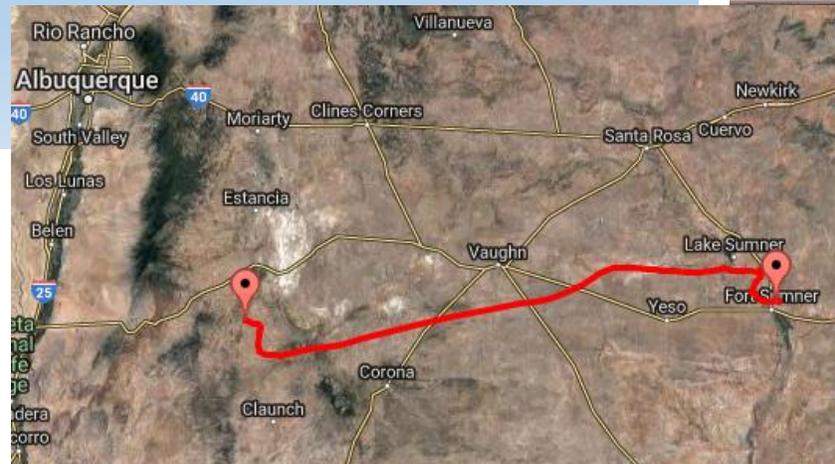
- ❖ Balloon: W29.47-2X-94
- ❖ Weight
 - ❖ Balloon: 3695 lb.
 - ❖ Suspended: 3136 lb.
- ❖ Float Altitude: 130 kft.
- ❖ Launched: 22 August 2019 / 13:59:16 Z
- ❖ Terminated: 22 August 2019 / 21:27:32 Z
- ❖ Total Float Time: 4 hrs. and 35 min.
- ❖ Fully recovered



11 MCF Piggyback – Flight 697N - Robert Salter, NASA CSBF – Fort Sumner Fall 2019.

- Piggyback missions on board include SPARROW, EMIDSS-1, and pGrampa.
 - SPARROW is a sensor package capable of measuring the relative wind seen by the gondola during ascent, float, and descent phases of flight. (GSFC IRAD)
 - EMIDSS-1 is a technological platform whose main purpose is to validate satellite sub-systems.
 - pGRAMPA is a single detector prototype of the planned GRAMPA experiment. The detector is a wide-field, collimated CsI scintillator sensitive to soft gamma-rays between 25 keV and 1 MeV.

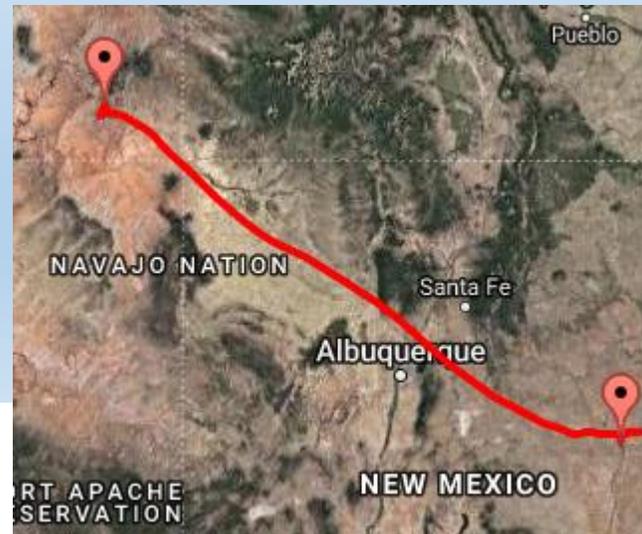
- ❖ **Balloon:** W11.82-1E-59
- ❖ **Balloon Weight:** 1659 lbs.
- ❖ **Suspended Weight:** 1414 lbs.
- ❖ **LSI:** 1206 psi.
- ❖ **Float Altitude:** 126 kft.
- ❖ **Launched:** September 4, 2019 / 13:42 Z
- ❖ **Terminated:** September 4, 2019 / 17:37 Z
- ❖ **Total Float Time:** 1 hours 27 minutes
- ❖ **Fully recovered**



High Altitude Student Platform – Flight 698N - Dr. T. Gregory Guzik, Louisiana State University – Fort Sumner Fall 2019.

- HASP is a collaborative effort to develop and operate an inexpensive platform that can be used to flight test compact satellites, prototypes and other small payloads designed and built by students.
- HASP is designed to carry up to twelve student payloads at a time to an altitude of about 120,000 feet with flight durations of 15 to 20 hours.
- HASP includes a standard mechanical, power and communication interface for the student payload to simplify integration and allow the payload to be fully exercised.
- HASP is lightweight and has simple mission requirements providing flexibility to schedule launch from Palestine, TX or Fort Sumner, NM anytime between April and September annually.

- ❖ **Balloon:** W11.82-1E-59
- ❖ **Balloon Weight:** 1655 lbs
- ❖ **Suspended Weight:** 1936 lbs.
- ❖ **LSI:** 1338 psi.
- ❖ **Float Altitude:** 122 kft.
- ❖ **Launched:** September 5, 2019 / 13:03 Z
- ❖ **Terminated:** September 5, 2019 / 23:18 Z
- ❖ **Total Float Time:** 7 hours 37 minutes
- ❖ **Fully recovered**



Balloon-borne Investigation of the Temperature and Speed of Electrons in the corona (BITSE/WASP) – Flight 699N - Dr. Natchimuthuk Gopalswamy, NASA GSFC – Fort Sumner Fall 2019.

- BITSE is a technology demonstration project.
- The long term scientific goal enabled by the BITSE technology will be to understand the physical conditions in the solar wind acceleration region (2-8 solar radii from the Sun center).
- To achieve this goal, the following scientific questions are investigated:
 - 1) What are the radial velocity and temperature profiles of the fast solar wind?
 - 2) Are the coronal streamer blobs realistic tracers of the solar wind?
 - 3) Is there evidence for interchange reconnection contributing to the slow solar wind?

- ❖ **Balloon:** W39.57-2-123
- ❖ **Balloon Weight:** 4136 lbs.
- ❖ **Suspended Weight:** 5672 lbs.
- ❖ **LSI:** 1743 psi.
- ❖ **Float Altitude:** 128 kft.
- ❖ **Launched:** September 18, 2019 / 14:52 Z
- ❖ **Terminated:** September 18, 2019 / 23:54 Z
- ❖ **Total Float Time:** 6 hours 25 minutes
- ❖ **Fully recovered**



Long Duration Balloon (LDB) Test Flight - Flight 700N *Chris Field, CSBF / David Stuchlik, NASA WFF BPO– Fort Sumner Fall 2019.*

- The LDB Test flight is an internal CSBF/WFF mission to raise the TRL of multiple CSBF systems in development or already flown, including the LCT2-20 TDRSS Transceiver, LightWeight Rotator, Hand Launch CDI Termination System, EVTm Test Telemetry System, SPB support systems, etc.
- The payload also supports the following Piggyback missions:
 - SUPERSEIS
 - GAPS Thermal
 - INMEX
 - MARSBOX
 - Cubes in Space

❖ Balloon:	W29.47-2X-103
❖ Balloon Weight:	3705 lbs.
❖ Suspended Weight:	4420 lbs.
❖ LSI:	1538 psi.
❖ Float Altitude:	125 kft.
❖ Launched:	September 23, 2019 / 14:00 Z
❖ Terminated:	September 23, 2019 / 20:34 Z
❖ Total Float Time:	4 hours 18 minutes
❖ Fully recovered	



Planetary Imaging Concept Testbed using a Recoverable Experiment – Coronagraph (PICTURE-C) - Flight 701N -

Dr. Supriya Chakrabarti, University of Massachusetts, Lowell – Fort Sumner Fall 2019.

- PICTURE-C will take the next steps along the road to characterizing Earthlike planets, in Earthlike orbits, orbiting Sunlike stars.
- It will demonstrate a high altitude balloon based clear aperture telescope with Low Order Wavefront Control (LOWC; Mendillo et al., 2012a), provide a flight demonstration of a high performance Vector Vortex Coronagraph (VVC; Mawet et al., 2011b), and raise the TRL of an integral field detector, the Microwave Kinetic Inductance Detector (MKID; Mazin et al., 2012).
- These technologies (LOWC, VVC, and MKID) have been developed under NASA funding; this effort will move them from ground based telescopes to flight systems.

❖ Balloon:	W39.57-2-113
❖ Balloon Weight:	4113 lbs.
❖ Suspended Weight:	5970 lbs.
❖ LSI:	1776 psi.
❖ Float Altitude:	128 kft.
❖ Launched:	September 28, 2019 / 15:07 Z
❖ Terminated:	September 29, 2019 / 11:14 Z
❖ Total Float Time:	16 hours 48 minutes
❖ Fully recovered	



PL Remote (MkIV/SLS) – Flight 702N – Dr. Geoffrey Toon, NASA JPL – Fort Sumner Fall 2019.

- This payload will make measurements of the composition of the stratosphere by using a suite of instruments.
- The MkIV is a solar occultation IR interferometer that measures over 30 chemical species. SLS is a submillimeter limb sounder that measures a dozen reactive radicals.
- The combined set of data provides a complete set of measurements for understanding a variety of processes that influence stratospheric ozone.

- ❖ **Balloon:** W29.47-2X-101
- ❖ **Balloon Weight:** 3705 lbs.
- ❖ **Suspended Weight:** 4694 lbs.
- ❖ **LSI:** 1373 psi.
- ❖ **Float Altitude:** 124 kft.
- ❖ **Launched:** October 7, 2019 / 14:30 Z
- ❖ **Terminated:** October 8, 2019 / 2:45 Z
- ❖ **Total Float Time:** 9 hours 47 minutes
- ❖ **Fully recovered**



Primordial Inflation Polarization Explorer (PIPER) – Flight 703N – Dr. Alan Kogut, NASA GSFC – Fort Sumner Fall 2019.

- PIPER is a balloon-borne instrument to measure the polarization of the cosmic microwave background (CMB) in search of primordial gravity waves created in an inflationary epoch in the early universe.
- It consists of twin telescopes cooled to nearly absolute zero, with 5120 superconducting detectors to achieve unprecedented sensitivity.
- PIPER's fast scan speed and unique polarization modulation allow it to survey half the sky in a single flight to measure the inflationary signal on the largest angular scales.

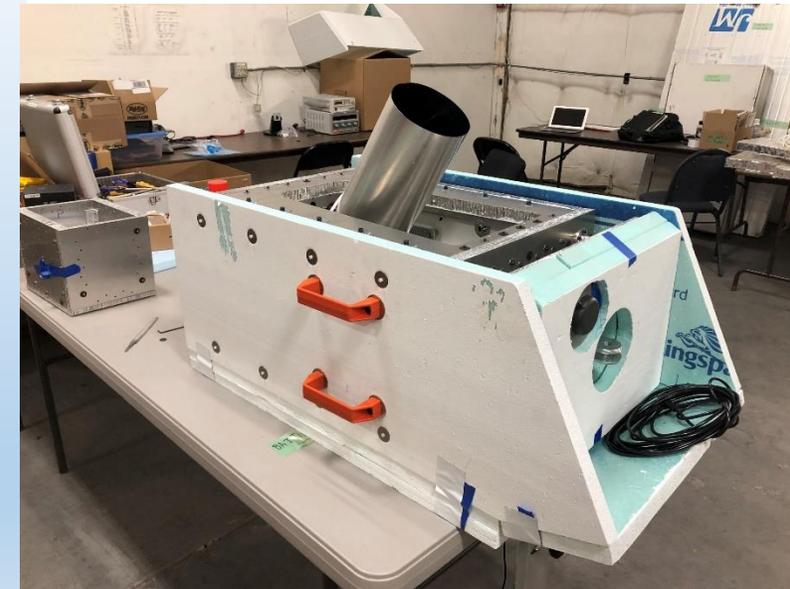
- ❖ **Balloon:** W11.82-3E-31
- ❖ **Balloon Weight:** 3100 lbs.
- ❖ **Suspended Weight:** 7450 lbs.
- ❖ **LSI:** 1373 psi.
- ❖ **Float Altitude:** 99 kft.
- ❖ **Launched:** October 14, 2019 / 13:36 Z
- ❖ **Terminated:** October 15, 2019 / 2:36 Z
- ❖ **Total Float Time:** 10 hours 50 minutes
- ❖ **Fully recovered**



Testbed for High Acuity Imaging –Stable Photometry Image-motion Compensation Experiment
QUARTER-SCALE FLIGHT (THAI-SPICE) – Flight 704N – Eliot Young, Southwest Research Institute –
Fort Sumner Fall 2019.

- Hand launch platform.
- A small (<70-lb) quarter-scale gondola instrumented with a network of thermal sensors.
- Test thermal models in the stratosphere and demonstrate passive thermal control measures.

- ❖ **Balloon:** A1.128-0-03
- ❖ **Balloon Weight:** 191 lbs.
- ❖ **Suspended Weight:** 71.5 lbs.
- ❖ **LSI:** 755 psi.
- ❖ **Float Altitude:** 125 kft.
- ❖ **Launched:** October 16, 2019 / 13:56 Z
- ❖ **Terminated:** October 16, 2019 / 19:05 Z
- ❖ **Total Float Time:** 3 hours 33 minutes
- ❖ **Fully recovered**



Reck-Tang Limbsounder (RECKTANGLE) – Flight 705N – Adrian Tang, NASA JPL – Fort Sumner Fall 2019.

- Hand launch platform.
- Extremely compact 180/600 GHz sub-millimeter wave spectroscopic instrument that is being developed for several astronomy and planetary science projects.
- Consumes less than 10W making it ideal for planetary missions to the outer solar system where mass and power are extremely limited.
- This flight will perform limb-sounding measurements on Earth's atmosphere similar to what would be performed on a planetary mission.

- ❖ **Balloon:** A1.128-0-02
- ❖ **Balloon Weight:** 191 lbs.
- ❖ **Suspended Weight:** 117.5 lbs.
- ❖ **LSI:** 736 psi.
- ❖ **Float Altitude:** 125 kft.
- ❖ **Launched:** October 17, 2019 / 13:54 Z
- ❖ **Terminated:** October 17, 2019 / 18:36 Z
- ❖ **Total Float Time:** 2 hours 1 minutes
- ❖ **Fully recovered**



Stratospheric Water Inventory, Tomography of Convective Hydration (SWITCH) – Nathaniel Livesey, NASA JPL – Fort Sumner Fall 2019.

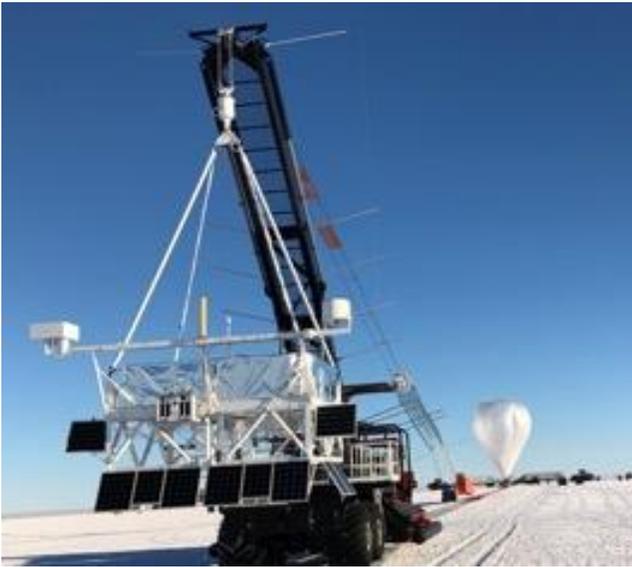
- Hand launch platform.
- A new class of active microwave occultation sounders aimed at making high spatial resolution observations of upper tropospheric and lower stratospheric water vapor (~10-20km) with a constellation of low-Earth-orbiting small satellites.
- As part of the project, plan to test the receiver/transmitter setup in a balloon-to-balloon configuration.
- Weather lead to the inability to launch the 1.1 MCF balloons simultaneously as required.
- Ground tests were conducted on 10/19/19 to provide proof of concept. Expecting a resubmission of the flight application.



Upcoming FY20 Antarctica Campaign

The FY20 Antarctica Campaign will begin in mid-November.

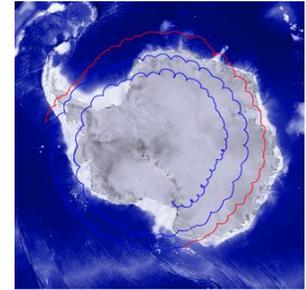
Two science missions (Super-TIGER and BLAST-TNG) are planned in addition to two small super pressure trajectory pathfinder balloons.



Super-TIGER was fully recovered and refurbished in FY19 and is scheduled for the FY20 campaign.



BLAST-TNG was winter-overed from FY19-FY20 due to the breakdown in the circulation (recovery of hard drives a requirement) and is scheduled for the FY20 campaign.

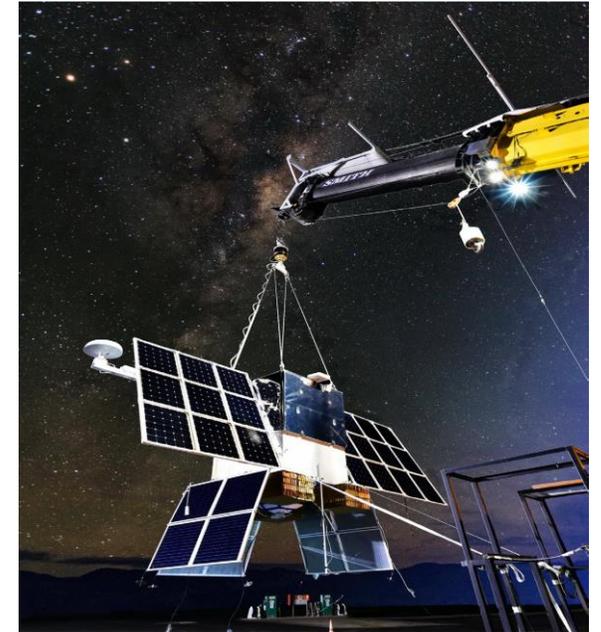


Two more SPB trajectory pathfinder balloons, with BARREL as mission of opportunity, are scheduled for the FY20 campaign.

The FY20 New Zealand Campaign will begin in mid-February with first flight ready date of March 26, 2020.

The next Super Pressure Balloon (SPB) Test Flight is scheduled to fly out of Wanaka, New Zealand in 2020. The Compton Spectrometer and Imager (COSI) will be the science mission of opportunity on the SPB.

Since the past SPB flight in 2017, a series of ground testing was conducted on 8.8 meter diameter models of the SPB. In addition, additional diagnostic instrumentation is being developed to provide general health & status, provide measurements/observations of critical areas, and provide in-flight data to validate current modeling tools.



- The Balloon Program has implemented new processes and procedures to address quality issues that arose over the past few years.
- The Balloon Program has conducted ground testing to study the impact of collar release angle and collar placement's impact on the balloon film which could have lead to the balloon leaks.
- The operational modifications implemented in the FY19 Fort Sumner campaign, resulted in 100% success rate for the campaign.
- Launch opportunities to fly the 60 million cubic foot balloon through the night will continue to be investigated in order to fully qualify the balloon for science.
- A small hand launch balloon system has been developed and qualified. This will be a new capability offered for science investigations.
- The Super Pressure Balloon development has a success oriented path to become qualified for the December 2021 need date for the Galactic/Extragalactic ULDB Spectroscopic Terahertz Observatory (GUSTO) mission, a NASA Explorer Mission of Opportunity.

